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(54) Title: METHOD AND APPARATUS FOR IN SITU SOIL REMEDIATION

(57) Abstract

Contaminated material such as soil or sludge is remediated by injecting a suitable remediation fluid into the material during excavation of the contaminated material with a trenching tool. The remediation fluid is injected into the contaminated material through an injection means, preferably a plurality of injection nozzles positioned along the length of the trenching tool. The thus treated material is backfilled or deposited directly into the trench excavated by trenching tool thereby obviating the need for off-site disposal. The constituent remediation agents in the remediation fluid may be adjusted to adapt to varying site conditions and contaminants. The remediation fluid may also be heated to accomplish volatile stripping of the contaminated material or to activate microbial agents in a low temperature environment.

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METHOD AND APPARATUS FOR IN SITU SOIL REMEDIATION

Field Of The Invention

The invention relates to a method and an apparatus for the in situ remediation of contaminated soil or sludge.

Background Of The Invention

It is widely recognized that years of unregulated industry have produced numerous environmentally hazardous sites throughout the country and the world which pose substantial health hazards to world's population. In recent years, efforts to clean up or remediate environmentally contaminated sites have increased dramatically, and numerous methods and devices for cleaning up or disposing of environmental contamination have been devised or proposed. However, the magnitude of the environmental problems is enormous, but the resources available to solve the problems are limited. Therefore, there is an urgent need for methods of remediation that are relatively uncomplicated, may be rapidly implemented, and are technically and cost effective.

Therefore, it is an object of this invention to provide a cost effective, relatively rapid method of remediating environmentally contaminated sites.

It is another object of this invention to provide a highly mobile apparatus for remediating environmental contaminants.

It is yet another object of this invention to provide a method of remediating contaminated soil in situ and without

removal or disposal of the treated or contaminated material.

It is yet another object of the invention to provide a method that is capable of remediating contaminated soils and sludges in a continuous, in contrast to a batchwise, manner.

It is yet another object of the invention to provide a remediation apparatus and method which may be used on highly unstable soils and in tight quarters such as in the basements of buildings or near above-ground or below-ground storage tanks.

The above objects and advantages of the present invention will become more apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

Summary Of The Invention

Contaminated material such as soil or sludge is remediated by injecting a suitable remediation fluid into the material during excavation of the contaminated material with a trenching tool. The remediation fluid is injected into the contaminated material through an injection means, preferably a plurality of injection nozzles positioned along the length of the trenching tool. The thusly treated material is backfilled or deposited directly into the trench excavated by the trenching tool thereby obviating the need for off-site disposal. The constituent remediation agents in the remediation fluid may be adjusted to adapt to varying site

conditions and contaminants. The remediation fluid may also be heated to accomplish volatile stripping of the contaminated material or to activate microbial agents in a low temperature environment.

In one aspect, the present invention is an injection treatment apparatus for remediating contaminated material at a contaminated site having a trenching mechanism means with a trenching tool and a means for positioning and powering the trenching tool. The apparatus has an injection means for injecting a remediation fluid into the contaminated material in close proximity to the trenching tool and a remediation fluid delivery means for conveying and delivering the remediation fluid to the injection means under pressure.

The injection means has at least one injection nozzle, preferably a plurality of injection nozzles, positioned to inject the remediation fluid into contaminated material excavated during operation of the trenching tool. The injection nozzles are preferably located at predetermined positions along the length of the trenching tool.

The remediation fluid delivery means has a remediation fluid storage means, a conduit means and a pump means for pumping the remediation fluid from the storage means through the conduit means to the injection means under pressure. Optionally, the remediation delivery means may have a heating means for heating the remediation fluid such as in the case of forced hot air.

The apparatus may also have a monitoring means for monitoring a selected physical or chemical property of the contaminated material such as pH, oxygen content, temperature or the like in the proximity of the trenching tool during operation of the apparatus and a means for adjusting the selected property of the contaminated material to a predetermined value, such as a means for adjusting the amount of a constituent remediation agent in the remediation fluid injected into the contaminated material during operation.

The apparatus may also comprise a volatile collection means for collecting volatile substances such as volatile hydrocarbons emitted from the contaminated material during treatment with the injection treatment apparatus.

In another aspect, the invention comprises a method for remediating a contaminated material at a contaminated site. The method comprises agitating the contaminated material with a trenching tool mechanism having a trenching tool and contemporaneously injecting a suitable remediation fluid into the agitated or excavated contaminated material in the proximate vicinity of the trenching tool to provide a treated material. The treated material is preferably deposited into the trench excavated by the trenching tool mechanism.

Where the contaminated material comprises a volatile constituent, the remediation fluid is preferably a fluid such as hot air for volatilizing a volatile constituent which is then collected using a collection means. In the case of a

liquid or semi-solid contaminated material such as a sludge or wastewater lagoon, the remediation fluid preferably comprises a solidification agent which is injected into the contaminated material thereby solidifying it and permitting further treatment. The method may also comprise monitoring a selected physical or chemical property of the contaminated material such as pH, oxygen content, temperature or the like and adjusting the selected property of the contaminated material to a predetermined value. For example, the pH may be maintained at a predetermined value by adjusting the amount of a constituent pH adjusting agent such as a pH buffer solution in the remediation fluid. The method may also comprise the step of heating the remediation fluid prior to injecting it into the contaminated material. This is useful where the remediation fluid comprises a microbial bioremediation agent and a gas such as air is heated sufficiently to activate the bioremediation agent in the contaminated material in a low temperature environment.

Brief Description Of The Drawings

FIG. 1 is a side elevation of the trenching tool portion of the trenching tool mechanism and the injection means.

FIG. 2 is a sectional view taken through line 2-2 of FIG. 1.

FIG. 3 is a schematic diagram of a trenching tool mechanism excavating contaminated soil and injecting a

remediation fluid along the length of the trenching tool.

Detailed Description
Of The Preferred Embodiments

In describing a preferred embodiment of the invention illustrated in the drawings, specific terminology will be used for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

With reference to the drawings, in general, and FIGS. 1 through 3 in particular, a trenching tool mechanism 10, injection means 41 and remediation fluid delivery means are shown.

The trenching tool mechanism 10 includes a mobile unit 20 mounted on tracks 21 having a boom 22 and hydraulic piston cylinder assemblies 24 and 26 for positioning trenching tool 30. Injection system 41 having injection nozzles 40 is mounted along the length of shaft 36 of trenching tool 30. The injection nozzles 40 are positioned below a plurality of digging tools 32 mounted on conveyor chain 34. As can be seen from the drawings, the injection nozzles are positioned such that the remediation fluid is injected below the soil surface while the contaminated soil is being excavated or comminuted by the trenching tool. The remediation fluid is thereby injected in the trench in the immediate vicinity of the

excavation or comminution of the contaminated soil along the trenching tool. In operation, conveyor chain 34 is driven about sprockets 44 at the ends of shaft 36. The trenching tool 30 is capable of excavating a trench of 3 to 30 feet in depth. The mobile unit 20 may be any suitable equipment such as a skid loader, backhoe, excavator, gradall or the like. The size of the trenching tool and mobile unit will vary depending upon site conditions.

The remediation fluid is pumped from storage tank 12 through conduit 14 to injection system 41 under pressure by a pump (not shown). The injection pressure may vary from about 10 psi to about 3,000 psi depending upon the desired remediation treatment. The remediation fluid may also be heated by a heating unit (not shown). The size and number of the injection nozzles may vary in accordance with the remediation treatment. For example, the nozzle size for pressurized hot air may range from about 1" to about 4" in diameter. Nozzle size for injecting a high pressure liquid may be 1/4" or smaller. The injection system may be pressurized by any suitable power source such as a hydraulic, electric or diesel power unit.

The remediation fluid delivery system may comprise a mixing unit for mixing constituent remediation agents from a plurality of storage tanks. Alternatively, parallel systems for delivering and injecting a plurality of remediation fluids may be employed. Such an embodiment is particularly useful,

for example, when two or more different remediation fluids such as a gas and a liquid are being injected into the contaminated soil simultaneously. The parallel system permits the multiple fluids to be injected through injection nozzles of different sizes at different pressures.

In operation, the contaminated soil 60 is excavated, and thereby comminuted and agitated, by trenching tool 30 in the direction of arrow 50. During excavation, a suitable remediation fluid is pumped through injection nozzles 40 of injection system 41 into the contaminated soil. The treated soil 55 is discharged into the trench thusly excavated by trenching tool 30 behind trench guard 42. A wide area of contaminated material such as contaminated soil or sludge at a site may be treated by trenching in parallel rows or any other suitable pattern across the entire area.

Any suitable remediation fluid, such as gases, liquids, slurries, or particulate solids, may be injected into the contaminated material in accordance with the process of this invention. The choice of remediation fluid and its constituents will depend upon site conditions and the contaminants sought to be remediated. By way of example, and without intending to be limited thereto, a liquid lime solution may be injected to stabilize a lead-contaminated site. A liquid biostimulant and appropriate microorganism such as are sold by Polybac Corp. of Bethlehem, Pennsylvania may be injected to treat contaminants such as mineral oil,

glycol or chlorinated phenols. Sludges may be solidified by injecting a solidification agent such as kiln dust into the contaminated sludge. If desired, a variety of remediation agents may be used in combination. For example, an oxygenation agent such as grade D breathing air may be used in combination with a bioremediation agent to aerate and accelerate the treatment of the contaminated material.

Stripping of volatile contaminants such as acetone, toluene, isopropyl alcohol, trichloroethanol, and the like may be accomplished by injecting hot air under pressure to volatilize the contaminants. The volatile contaminants may be collected by any suitable collection system such as a tent-like structure having a positive pressure circulation system with a carbon filter. Such a collection system is available from Sprung Structures, Inc. of Allentown, Pennsylvania. The apparatus of the present invention may be sized to operate within the tent-like structure.

The present invention may be used to remediate contaminated sites which were heretofore untreatable. For example, bioremediation of contaminated soil may not, in general, be achievable in low temperature environments, typically environments having temperatures below about 40° F. The low temperatures tend to incapacitate or kill the microorganisms that accomplish the remediation. However, the present method provides for the injection of a heated gas such as hot air in combination with the bioremediation agent

thereby raising the temperature at the locus of treatment and activating the bioremediation agent. This has the beneficial effect of permitting bioremediation of contaminated soils in cooler or arctic climates and/or extending the effective season during which bioremediation may be accomplished in temperate climates.

In another instance, the present invention provides for the injection of remediation fluids in dense, clay-laden soils. The prior art methods of injection are ineffective in treating non-porous, clay-laden soils, because the injected remediation fluid is unable to migrate throughout the soil. However, according to the present invention, clay-laden soils may be effectively remediated, because the method comminutes the soil during excavation by the trenching tool.

The present invention is principally intended for the treatment of contaminated soil. However, a wide variety of contaminated materials, including semi-solid sludges and wastewater lagoons, may be treated in accordance with the invention. In the case of a lagoon, the injection treatment apparatus may act as a kind of large-scale, mobile mixer for agitating and injecting a remediation fluid into the wastewater. The wastewater may be first treated to neutralize contaminants in the water, and subsequently treated with a solidification agent. Alternatively, the wastewater may be first injected with a solidification agent to form a contaminated "soil", and then injected with a second

remediation fluid to neutralize the contaminants.

Although this invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made which clearly fall within the scope of the invention. The invention is intended to be protected broadly within the spirit and scope of the appended claims.

Claims

What is claimed is:

1. An injection treatment apparatus for remediating a contaminated material at a contaminated site comprising:

a trenching mechanism means comprising a trenching tool for comminuting contaminated material and a means for positioning and powering the trenching tool;

an injection means for injecting a remediation fluid into the contaminated material in close proximity to the trenching tool comprising an injection nozzle means positioned and adapted to inject the remediation fluid below the surface of the contaminated material while the material is being comminuted by the trenching tool; and

a remediation fluid delivery means for conveying and delivering the remediation fluid to the injection means.

2. An apparatus according to claim 1, wherein the injection means comprises at least one injection nozzle positioned to inject the remediation fluid into contaminated material excavated during operation of the trenching tool.

3. An apparatus according to claim 2, wherein the injection means comprises a plurality of injection nozzles.

4. An apparatus according to claim 3, wherein the injection nozzles are located at predetermined positions along

the length of the trenching tool.

5. An apparatus according to claim 1, wherein the remediation fluid delivery means comprises a remediation fluid storage means, a conduit means and a pump means for pumping the remediation fluid from the storage means through the conduit means to the injection means under pressure.

6. An apparatus according to claim 5, wherein the remediation delivery means further comprises a heating means for heating the remediation fluid.

7. An apparatus according to claim 1, wherein the injection treatment apparatus further comprises a monitoring means for monitoring a selected physical or chemical property of the contaminated material in the proximity of the trenching tool during operation of the apparatus and a means for adjusting the selected property of the contaminated material to a predetermined value.

8. An apparatus according to claim 7, wherein the means for adjusting the selected property comprises a means for adjusting the amount of a constituent remediation agent in the remediation fluid injected into the contaminated material during operation of the apparatus.

9. An apparatus according to claim 1, wherein the apparatus further comprises a volatile collection means for collecting volatile substances emitted from the contaminated material during treatment with the injection treatment apparatus.

10. A method for remediating a contaminated material at a contaminated site comprising:

agitating the contaminated material with a trenching tool mechanism having a trenching tool; and

injecting a remediation fluid into the contaminated material in the proximity of the trenching tool below the surface of the contaminated material while the amaterial is being agitated by the trenching tool to provide a treated material.

11. A method according to claim 10, wherein the method further comprises the step of depositing the treated material into a trench excavated by the trenching tool mechanism.

12. A method according to claim 10, wherein the remediation fluid comprises a fluid for volatilizing a volatile constituent in the contaminated material, and the method further comprises the step of collecting the volatilized volatile constituent.

13. A method according to claim 10, wherein the contaminated material is a liquid or semi-solid, the remediation fluid comprises a solidification agent, and the injection of the remediation fluid solidifies the contaminated material.

14. A method according to claim 13, wherein the method further comprises the steps of:

agitating the solidified, contaminated material with the trenching tool mechanism; and

injecting a second remediation fluid into the solidified, contaminated material in the proximity of the trenching tool to provide a treated material.

15. A method according to claim 10, wherein the method further comprises the steps of:

monitoring a selected physical or chemical property of the contaminated material; and

adjusting the selected property of the contaminated material to a predetermined value.

16. A method according to claim 15, wherein the selected property is the pH of the contaminated material, and the pH is maintained at a predetermined value by adjusting the amount of a constituent pH adjusting agent in the remediation fluid.

17. A method according to claim 10, wherein the method further comprises the step of heating the remediation fluid prior to injecting it into the contaminated material.

18. A method according to claim 10, wherein the remediation fluid comprises a bioremediation agent and a gas heated sufficient to activate the bioremediation agent in the contaminated material.

19. A method according to claim 10, wherein the contaminated material is laden with dense clay.

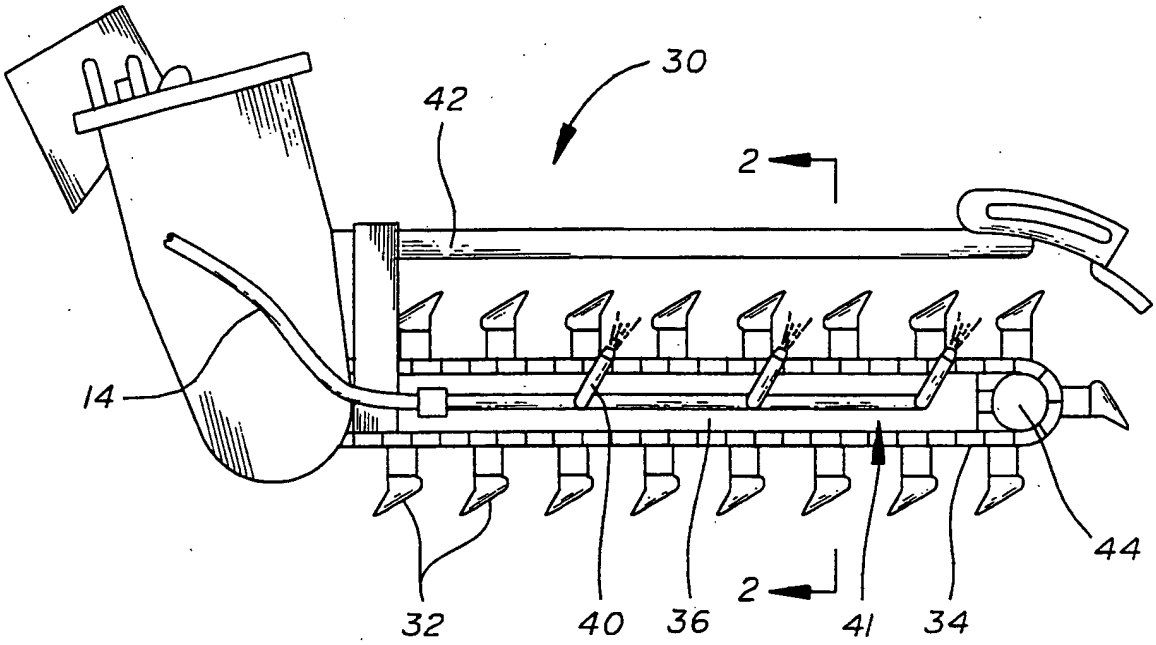

Fig. 1

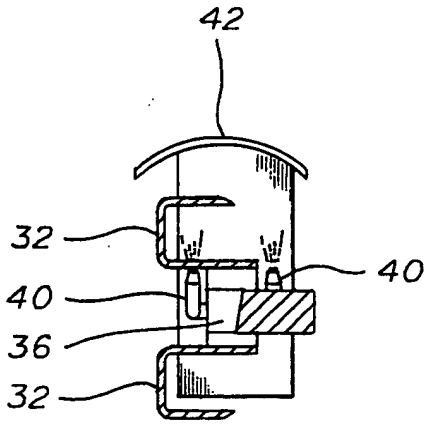

Fig. 2

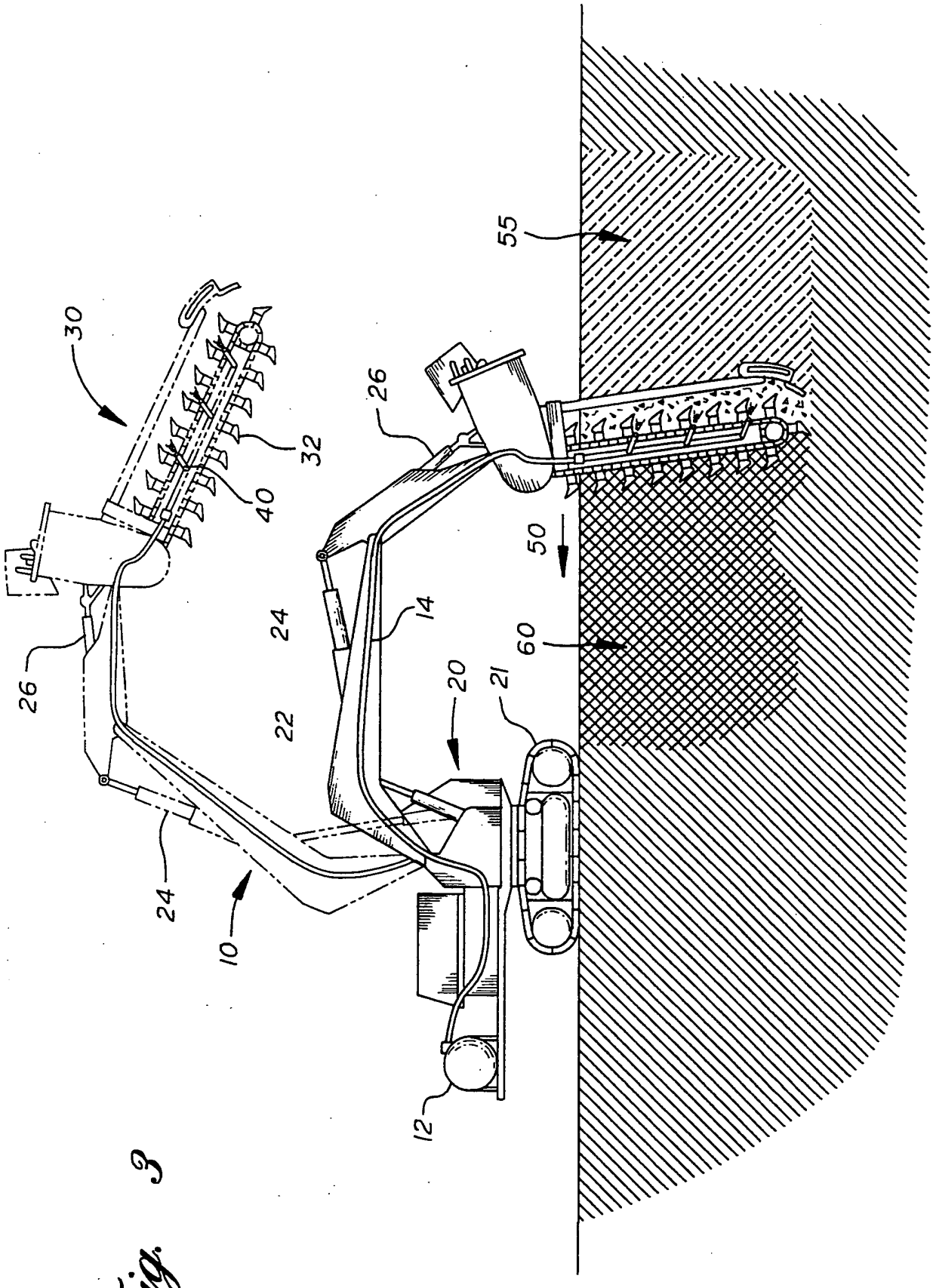

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/05127

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B09B 3/00; C12S 13/00; E02D 3/12
US CL :405/263, 264, 266, 128, 130; 435/262, 262.5
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 405/263, 264, 266, 128, 130; 435/262, 262.5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms:biodegrade, degrade, clay, soil, tilling, inject, trenching

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US, A, 5,242,246 (MANCHAK, III ET AL) 07 September 1993, see entire document.	1-19
Y	US, A, 4,849,360 (NORRIS ET AL) 18 July 1989, see columns 1-2.	18
Y	US, A, 4,447,541 (PETERSON) 08 May 1984, see the abstract.	15-16
Y	US, A, 5,169,263 (JOHNSON ET AL) 08 December 1992, see the abstract and columns 1-2.	12, 17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
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Date of the actual completion of the international search
01 AUGUST 1994

Date of mailing of the international search report
AUG 22 1994

Name and mailing address of the ISA/US
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/05127

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☒ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

I. Claims 1-12, 15-17 and 19 drawn to a first appearing apparatus for in-situ treatment of contaminated soil, classified in Class 405, subclass 264, and a first appearing method of treating contaminated soil by volatilization of the contaminant, classified in Class 405, subclass 130.

II. Claims 13-14, drawn to a second appearing method of treating contaminated soil by solidification of the contaminant, classified in Class 405, subclass 266.

III. Claim 18, drawn to a third appearing method of treating contaminated soil by bioremediation of the contaminant, classified in Class 435, subclass 262.5.

The inventions listed as Groups I-III do not meet the requirements for Unity of Invention for the following reasons: Inventions I (volatilization method), II and III are separate and distinct methods having no special relationship common to each and requiring different starting materials, using different treatment steps and achieving distinct results. Inventions I (apparatus) and II-III are related as an apparatus and processes of use. The inventions have no special relationship common to each because the methods do not require that the injectors be part of the trenching tool. Also, the apparatus has several distinct uses, such as any of the three distinct methods of the present claims. Accordingly, the claims are not so linked by a special technical feature within the meaning of PCT Rule 13.2 so as to form a single inventive concept. Note that PCT Rules 13.1 and 13.2 do not provide for multiple products and methods within a single application.